George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

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Baseline
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Project Plan

For

Airframe Technology

Spaceliner 100 Investment Area

Advanced Space Transportation Program Office/TD15
Space Transportation Directorate
NASA Marshall Space Flight Center

Aero-Space Vehicle Systems Technology Program Office
NASA Langley Research Center

AIRFRAME TECHNOLOGY PROJECT PLAN

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LIST OF ACRONYMS

APRS	Automated Procurement Request System
ARC	Ames Research Center
ASTP	Advanced Space Transportation Program
AVSTP	Aero-Space Vehicle Systems Technology Program
COC	Certificate of Compliance
CTLM	Continuous Tape Laying Machine
CWC	Collaborative Work Commitments
DFRC	Dryden Flight Research Center
DoD	Department of Defense
E-beam	Electron Beam
EAA	Enterprise Associate Administrator
ELV	Expendable Launch Vehicle
FY	Fiscal Year
GPMC	Governing Program Management Council
GRC	Glenn Research Center
ISO	Industrial Safety Office
JSC	Johnson Space Center
LaRC	Langley Research Center
LOX	Liquid Oxygen
MM.	MSFC Manual
MMI	MSFC Management Instruction
MPS	Main Propulsion System
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NHB	NASA Handbook
NPD.	NASA Program Directive
NPG	NASA Procedures and Guidelines
NRA	NASA Research Announcement
PCA	Program Commitment Agreement
PCC	Program (Project) Cost Commitment
PDR	Preliminary Design Review
PMC	Project Management Council
PMC	Polymer Matrix Composite
R&T	Research and Technology
RLV	Reusable Launch Vehicle
S&MA	Safety and Mission Assurance
SmarTPS	Subsurface Microsensors for Assisted Recertification of Thermal Protection

	Systems
STD	Space Transportation Directorate
TBD	To Be Determined
TPS	Thermal Protection System
UHCT	Ultra-High Temperature Ceramics
WBS	Work Breakdown Structure

FOREWORD

This Project Plan describes the planning and objectives for the implementation of a NASA project known as the Airframe Technology Project. This plan has been prepared in accordance with the *NASA Program and Project Management Processes and Requirements*, NPG 7120.5A, and is consistent with the *NASA Strategic Management Handbook* and *NASA Program/Project Management*, NPD 7120.4.

I. INTRODUCTION

The Airframe Technology Project as part of the Aero-Space Base Research and Technology (R&T), will pioneer the identification, development, verification, transfer, and application of high-payoff space transportation airframe technologies. The program fits within the NASA strategic vision that *"NASA is an investment in America's future. As explorers, pioneers, and innovators, we boldly expand frontiers in air and space to inspire and serve America and to benefit the quality of life on Earth."* The NASA Strategic Plan establishes a framework for making management decisions by separating the Agency's programs into four externally focused Strategic Enterprises. One of these enterprises, the Aero-Space Technology Enterprise, has characterized its long-range strategy in the form of three pillars for success. The Airframe Technology Project supports the third pillar, Access to Space, of the Enterprise.

The Airframe Technology Project as part of the Aero-Space Base R&T, which is part of the Aero-Space Technology Enterprise, provides a foundation for the airframe technologies needed to provide a steady influx of concepts available for future use by the U.S. aeronautics and space industry and the other NASA Enterprises.

This Airframe Technology Project Plan provides an authoritative, management description of the project, and is the controlling document for project content and organization. This plan is responsive to the requirements of the NASA Program and Project Management Processes and Requirements (NPG 7120.5A), but has been tailored to meet the needs of the Aero-Space Base R&T program management. The primary purpose of the plan is to establish the following:

- Project objectives and performance goals;
- Project requirements;
- Management and implementing organizations responsible for the project; and
- Project resources, schedules, and controls.

This plan will be updated annually to reflect project progress and strategic redirection.

II. OBJECTIVES

The Airframe Technology Project principally supports the third pillar, Access to Space, of the Aero-Space Technology Enterprise concentrating on the following Enterprise goal:

- Develop and demonstrate pre-competitive, next generation technology that will enable US Industry to reduce costs by an order of magnitude ($1000 per pound) within 10 years. Conduct research and technology development and demonstrations, which will enable US industry to further reduce costs by an additional order of magnitude ($100 per pound) within 25 years.

Dramatically improved safety, operability, and reduced costs are required to meet the growing challenge facing today's US space program. For decades, the US space program has been in a global leadership position. However, current launch costs consume valuable resources and are limiting access to space for both the private and public sectors. As a result, the primary, overarching, continuing goal of NASA's space transportation technology programs, derived from National Space Policy and the NASA Strategic plan, is to significantly reduce the cost of space transportation systems while improving reliability, operability, responsiveness, and safety.

The project is part of both the Aero-Space Vehicle Systems Technology Program and the Advanced Space Transportation Program, both of which are part of the Aero-Space Base R&T. The objective of the Airframe Technology Project is to develop and demonstrate airframe technologies that provide a significant reduction in the cost of space transportation systems while dramatically improving the safety and higher operability of those systems. The project is part of the Spaceliner 100 investment area within the AVSTP and ASTP. It is responsible for developing and demonstrating airframe technologies required for 3rd generation reusable launch vehicles. In this case, the airframe technologies include materials, structures, thermal protection systems, cryogenic tanks, aero/aerothermodynamics, propulsion/airframe integration, and systems analysis. Facility enhancements are addressed within the project but only when required by planned research.

III. CUSTOMER DEFINITION AND ADVOCACY

The primary customers for the Airframe Technology Project are NASA's Advanced Space Transportation Program (ASTP) and Vehicle Systems Technology Program. ASTP is interested in the development and test of technologies that will potentially provide low-cost space transfer, have low development costs, and that will show near-term results. The Airframe Technology customer base is all inclusive of those taking advantage of the technologies developed. They include:

- Universities/Academia
- Office of Earth Science (OES)
- Office of Space Science (OSS)
- Office of Life & Microgravity Sciences & Applications (OLMSA)
- Office of Aero-Space Technology (OAT)
- Office of Human Exploration and Development of Space
- Department of Defense (DoD)
- Industry

IV. PROJECT AUTHORITY

The *NASA Strategic Plan* and the *NASA Strategic Management Handbook* assign to MSFC the Lead Center responsibility for Space Transportation Systems development. This assignment includes Lead Center responsibility for the Advanced Space Transportation Program of which the Airframe Technology Project is a part. In addition, Langley Research Center has been designated as the Lead Center for the Vehicle Systems Technologies Research and Technology Base Program. The Airframe Technology Project reports to both programs. The Airframe Technology Project Office is responsible for project implementation and management. The Airframe Technology Project Office has direct commitments with MSFC and other NASA centers through the prime contractors or between the Project Office and NASA Centers. The MSFC and LaRC PMCs are responsible for oversight of the Airframe Technology Project.

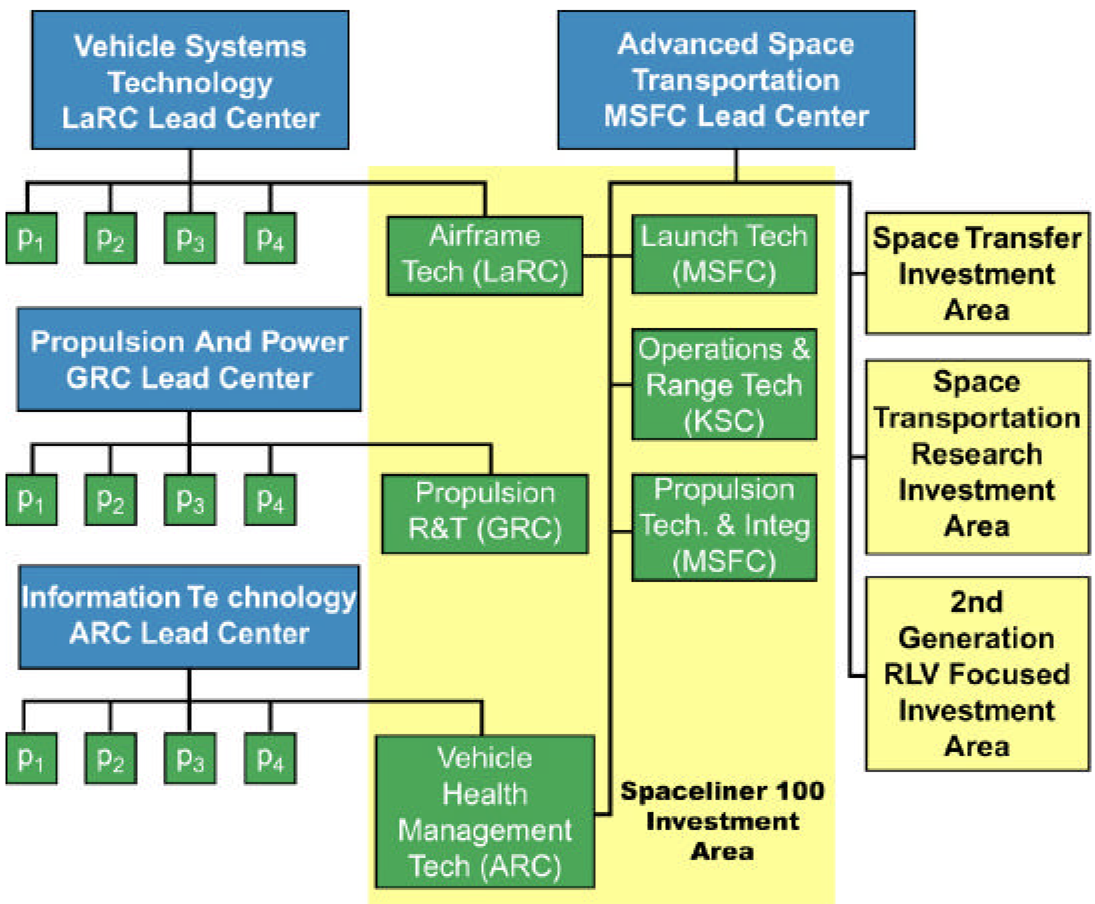

Figure IV.1. Relationship between the Base R&T Programs and the Airframe Technology Project.

V. MANAGEMENT

A. Organization and Responsibilities

1. NASA Headquarters

The Office of Aero-Space Technology (Code R) is the NASA Headquarters office responsible for the Airframe Technology Project.

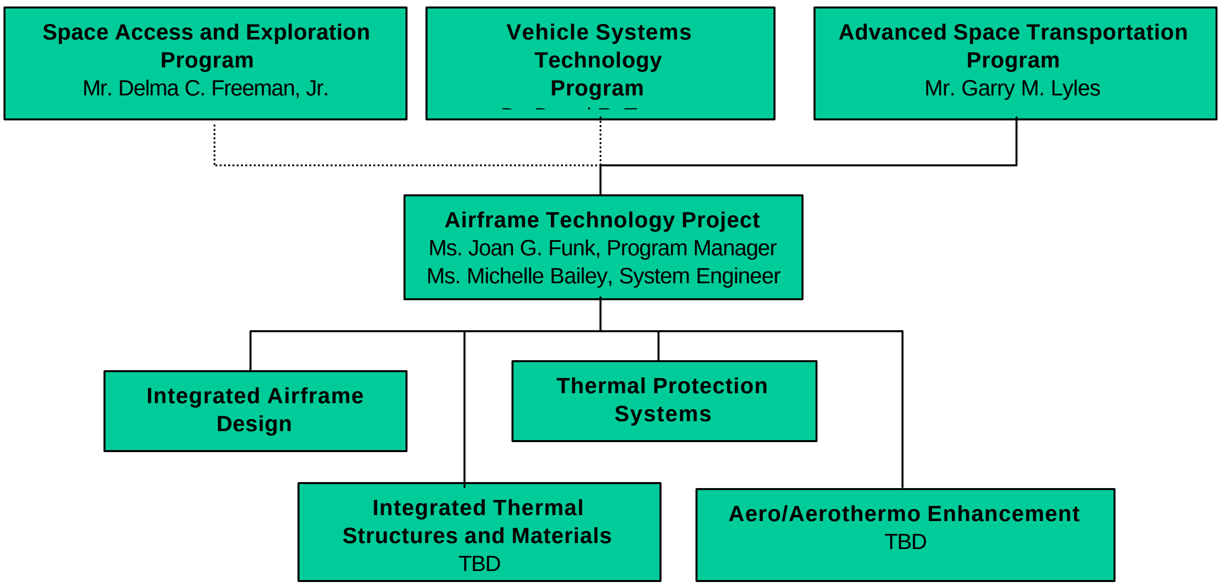

Figure V.1. Airframe Technology Project Management Structure

2. Field Centers

The relationship between the Base R&T Programs and the Airframe Technology Project is shown in Figure V.1. The field centers involved in the Airframe Technology Project include: Marshall Space Flight Center, Langley Research Center, Ames Research Center, Glenn Research Center, Dryden Flight Research Center, and Johnson Space Center. Work is assigned to each Center based on agreed upon Center roles and missions. The involvement of each center is described below:

a. Marshall Space Flight Center (MSFC)

The MSFC, as the lead center for Space Transportation Systems Development and the Center of Excellence for Space Propulsion, is the principal NASA Center for research, technology maturation, design, development, and integration of space transportation and

propulsion systems, including both reusable and expendable launch vehicles, and vehicles for orbital transfer and deep space missions.
The Advanced Space Transportation Program, X-33, and Future-X/Pathfinder Program Offices have been consolidated with other space transportation development and technology activities at the MSFC into a new organizational unit, the Space Transportation Directorate. This consolidation enables integrated coordination of ongoing advanced space transportation activities together with strategic planning for new initiatives, and will provide a single focal point for the lead center responsibilities within the mission area of space transportation. The Space Transportation Directorate is responsible for executing the NASA Lead Center role assigned to MSFC for space transportation systems development activities. This responsibility includes program and project level planning, research, and development to ensure a well balanced space transportation development program that meets the Agency's aggregate needs in a coordinated and integrated manner.

Manager, Advanced Space Transportation Program, manages and integrates activities for conducting research and technology maturation and demonstrations applicable to advanced space transportation systems. The ASTP Program Manager serves as principal advisor to the MSFC Assistant Director for Space Propulsion Systems concerning planning, implementation, and evaluation of MSFC's assignment as Propulsion Center of Excellence. The established programs, ASTP, X-33, and Future-X/Pathfinder functionally report to the MSFC Center Director. All program office personnel are being assigned administratively to the Space Transportation Director. The individual program offices are kept small and share administrative staff, program control as well as collocated engineering and procurement support.

Responsibility for the Airframe Technology Project falls under the ASTP and AVSTP. Tasks in this project will be managed by the appropriate Center based on agreed upon Center roles and missions. The Airframe Technology Project Manager works with representatives from all involved centers to plan, coordinate and interface with other projects and organizations as appropriate to accomplish the job.

Program Management (Level II)

Overall Program Management is provided by the Advanced Space Transportation Program Office.

Project Management (Level III)

See section b. Langley Research Center

Engineering Management (Level IV)

The Lead Systems Engineer is assigned by the ASTP Manager and reports to the Project Manager. The Lead Systems Engineer is responsible to the project for ensuring that all engineering aspects of funded tasks, including in-house, other centers and contractor responsibilities are accomplished within the technical requirements and cost and schedule restraints.

The products of the Lead Systems Engineer are:

- CWCs that support project schedule.
- Level IV directives releasing drawings, documentation and change control documentation.
- COTR support and documentation for contracts that support the project tasks.
- Design review agendas, review team coordination, and pre-board disposition.

b. Langley Research Center (LaRC)

Langley has been designated as the Lead Center for the Vehicle Systems Technologies Research and Technology Base Program.

Project Management (Level III)

The Project Manager is assigned by AVSTP office and reports to the ASTP Program Manager (Level II), Vehicle Systems Technology Program Manager, and Space Access and Exploration Program Manager as shown in figure V.2. The Project Manager is responsible for developing an approach to meet the objectives established by the ASTP Program Manager; developing lower level project constraints such as budget, resources and schedule; and implementation planning that coordinates NASA and contractor assets.

The products of the Project Manager are:

- **Project Plan**. The Project Plan shall be written in accordance with NPG 7120.5A
- **Integrated Project Schedule**. The Integrated Project Schedule shall consist of level 1 and level 2 milestones. All lower level milestones shall be tracked at the task level. The project schedule shall contain the baseline schedule and deviations from the baseline. The Project Manager must approve changes to the baseline project schedule. The Project Manager has the authority to approve changes to the level 3 milestones. The Project Manager
- **Resource Allocations** (POP inputs). The Resource Allocations contain estimates of budget requirements and workforce requirements. This report indicates when

budgeted funds will be obligated and costed as well as the cost of in-house manpower and it's phasing. The Project Manager is assisted by a business manager who is assigned by the ASTP management. The business manager's primary responsibility is to assure that all procurements are planned and purchased in time to support the project schedule. The Business Manager shall work with the PDTs to evaluate procurement needs and schedule; track expenditures; and reports progress and issues to the project manager.

- **Collaborative Work Commitments** (CWC). The Project Manager will use the appropriate Center system to develop workforce requirements for each Center participating in the Airframe Technology Project. The Project Manager will develop CWCs per MSFC-P03.1-C01 for work conducted at MSFC. Lead Systems Engineer will assist the Project Manager. CWCs are controlled by the Project Manager and held as a quality record in accordance with MSFC-P16.1 for 6 months after completion of the task.

c. Ames Research Center (ARC), Glenn Research Center (GRC), LaRC, and MSFC

Engineering Management (Level IV)

FY00 is a transition year for the Airframe Technology Project. Subelement leaders have been assigned for each funded task within the project that is lead by ARC, GRC, LaRC, and MSFC. Their role will be technical with regard to the nature of the work being conducted in the task. Each subelement leader will submit a monthly report to the Airframe Technology Project Manager. These reports will summarize significant technical and programmatic progress over the past month, resource and schedule variances, and major issues as well as planned major activities for the coming month. As the project moves into FY01 planning and implementation, it is envisioned that element leads, as shown in fig V.2, will be appointed to plan an integrated element instead of a set of discrete tasks. Element leads and subelement task leaders will be chosen based on Center roles and missions

d. Dryden Flight Research Center (DFRC) and Johnson Space Center (JSC)

Currently the Dryden Flight Research Center and Johnson Space Center play a supporting role to tasks within the Airframe Technology Project that are managed by another Center.

B. Special Boards and Committees

As part of AVSTP, the project will be reviewed during the Office of Aero-Space Technology Advisory Committee's review of the AVSTP.

C. Management Support Systems

The following management systems will be utilized with the Airframe Technology Project as appropriate. In addition, other systems within the agency are being reviewed and considered as potentials.

1. Virtual Research Center (VRC)

The VRC is an Internet-based project management and document management system that allows all project team members access to project documents, drawings, meeting notes, assigned action items and the group calendar.

2. Other Management Systems

Current plans call for the implementation by June 1, 2000 of the Integrated Financial Management Planning (IFMP) system. This is a mandatory, agency wide tool for budgeting, tracking and analyzing funding.

For portions of the project being conducted at MSFC the following will be systems will be used:

3. Marshall Resources Tracking System (MARTS)

The MARTS system for tracking funding authority, commitments, obligations, cost and disbursements will be utilized by Airframe Technology Project.

4. Workforce Information System (WIS)

The WIS system will be utilized for tracking the civil service workforce associated with Airframe Technology Project.

5. Automated Procurement Request System (APRS)

The S&E APRS system will be used for the Procurement Requests (Form 424) process.

VI. TECHNICAL SUMMARY

As part of the Aero-Space R&T Base, the Airframe Technology Project will push the state-of-the-art in airframe and vehicle systems for low-cost, reliable, safe space transportation. The individual technologies within the project are focused on advanced, breakthrough technologies in airframe and vehicle systems and cross-cutting activities that are the basis for improvements in these disciplines. The key issues that will be addressed by the project are integrated airframe design, integrated thermal structures and materials, thermal protection systems, and aero/aerothermodynamics enhancements. Each of the tasks within this project are described in the following paragraphs.

Currently work in the project consists of work originally part of the airframe element of the Bantam Project and work that is currently being planned under the auspices of the Integrated Space Transportation Plan. Given the current state of planning, this document will detail the transferring Bantam Project tasks, new FY00 tasks, and will broadly describe the remainder of the project.

A. Level 1 Milestones (FY00 and FY01)

Level 1 milestones included in the ASTP and AVSTP plans are listed below. Level 2 milestones are listed in Section VII.

- 2QFY00 - Complete preliminary design of Liquid Oxygen (LOX) tank for X-34

  Output: Hold preliminary design review of composite LOX tank for X-34.
  Outcome: The tank being fabricated in this activity will become the first composite liquid oxygen tank to be flight tested. The long-term impact of utilizing low cost lightweight composites in liquid oxygen tank applications will be to reduce the cost of access to space.

- 4QFY00 - Complete testing of modified carbon-carbon control surface
  Output: Documentation of room and elevated temperature testing of modified torque tube control surface.
  Outcome: Refractory composite hot-structures control surfaces have the potential to eliminate the TPS requirement for advanced reusable launch vehicles which could potentially reduce weight, and reduce operation and maintenance requirements.

- 4QFY00 - Characterization of various felt Thermal Protection System (TPS) concepts
  Output: Measurement of thermal and mechanical properties, thermo-chemical stability assessment and durability screening in a vibro-acoustic environment of a variety of felt TPS concepts.
  Outcome: - High temperature felts contribute to lower initial and recurring costs for reusable launch vehicles while enhancing the vehicle’s rapid turn-around capability.

- 1QFY01 Complete preliminary design of SHARP L-1
  Output: Hold preliminary design review of SHARP L-1.

Outcome: SHARP L-1 will demonstrate a variety of sharp body technologies which will allow an entirely new generation of aero-space vehicle designs that have substantially improved affordability and capabilities for space access.

B. Integrated Airframe Design

The long-term major goals from the integrated airframe design element are envisioned to include the following:

- Integrated advanced design and analysis technologies leading to substantial reductions in design cycle time
- Ultra-rapid variable-fidelity modeling, accurate analysis, and redesign of structural concepts
- Verified fail-safe airframe analysis and design methodologies

In FY00 there are two tasks in the Integrated Airframe Design element both of which will contribute to the verified fail-safe airframe analysis and design methodologies goal.

1. Polymer Matrix Composite Damage Tolerance

The first task, Polymer Matrix Composite Damage Tolerance, will test fiber/resin systems for damage tolerance. The most damage prone areas (either in manufacturing or in service) of a part will be identified and various levels of damage will be imparted into test specimens in these areas. Tests of how the damage effects the critical properties of the part will then be assessed and documented. Analytical efforts will be carried out to assess the load carrying ability of the structure with these defects under the appropriate combined loading conditions. Damage tolerant design of composite structures will extend of the life of RLVs, improve safety, and reduce weight through improved understanding and reduced variability in design. Structures designed with damage tolerance design allowables also require less frequent inspections which reduces maintenance costs.

2. Safe Structures Analysis and Design Technologies

The second task, Safe Structures Analysis and Design Technologies, is developing verified fail-safe and reliability-based structural analysis and design methodologies for highly reliable composite structures subjected to combined loads. The development of verified composite structures analysis and design technologies that enable fail-safe design will potentially lead to more efficient and reliable structures for RLVs.

C. Integrated Thermal Structures and Materials

The long-term major goals from the integrated thermal structures and materials element are envisioned to include the following:

- Development of new metallic and polyimide foams, metal alloys, ceramic matrix composites, metallic matrix composites, and hybrid metallic and polymeric composites
- Near net and free form manufacturing of large, unitized metallic structure, non-autoclave manufacturing processes and low cost, automated assembly technology
- Develop advanced and smart/adaptive, hot (up to 3000 deg. F) and cooled airframe structures
- Develop advanced cryotanks of advanced organic composites and metallic alloys and metal matrix composites.

There are currently several funded tasks in the integrated thermal structures and materials element**.**

1. Integrated MPS Cryotank System

The first task, Integrated MPS Cryotank System, is developing and demonstrating technologies required for an integrated composite cryogenic conformal common bulkhead aerogel insulated tank. A composite aerogel-insulated tank has the potential for significant weight savings over traditional metallic tank designs

2. Advanced Adhesives and Sealants

The second task, Advanced Adhesives and Sealants, is developing hot-melt adhesives and sealants for –180 deg. to +550 deg. F application, and potentially for non-autoclave curing. The approach is to formulate the hot-melt adhesives with BMI, cyanate esters and epoxies. A lap shear adhesive strength test using titanium substrates will be used to screen the adhesives.

3. Non-autoclave Fabrication of Polymer Matrix Composites (PMCs)

The third task, Non-autoclave Fabrication of PMCs, is developing and validating e-beam curable composite processing on a continuous tape laying machine (CTLM), and optimizing e-beam curable properties for high temperature applications (550 deg. F). E-beam curing enables fabrication of PMC components at room temperature, leading to reduced tooling costs, cure times, and improved component durability.

4. Carbon-Carbon Control Surface Modifications

The fourth task, Carbon-Carbon Control Surface Modifications, is defining least weight moveable control surfaces for advanced launch vehicles and then verifying the design, fabrication technology, and structural adequacy of these control surfaces by performing thermal structural load verification tests. These types of control surfaces, made from refractory composites, have the potential to eliminate the need for thermal protection systems, reducing weight, operations, and maintenance requirement.

5. Ultrasonic Spectroscopy for Composite Adhesive Bond Strength Determination

The fifth task, Ultrasonic Spectroscopy for Composite Adhesive Bond Strength Determination, is developing and demonstrating the use of ultrasonic spectroscopy for determination of adhesive bond strength in composite structures. The final products will be the correlation between ultrasonic resonance spectra and mechanical property measurements of various composite bond specimens. Quantitative information regarding the integrity of adhesive bonds in composites is a critical technology to enable the use of large, reusable composite structures, and realize the significant weight savings they offer.

6. Stitched, High Temperature Polymer Composite Cryotank Technology

The sixth task, Stitched, High Temperature Polymer Composite Cryotank Technology, is developing and demonstrating technologies for stitched, high temperature polymer composite cryogenic tank structures. The final products will be new/modified polymer matrix formulations, design concepts, demonstration hardware, and subcomponent testing. Stitched preforms combined with high temperature polymer matrix materials offer the potential for significant weight and durability advantages over more conventional composite facesheet/ honeycomb core concepts.

7. Advanced Composite LOX Tank for X-34

The seventh task in this element, Advanced Composite LOX Tank for X-34, is designing, fabricating, and delivering a composite LOX tank for X-34. The tank will be the first actual flight test of a composite LOX tank.

8. Graphite/PETI-5 Composite Aero Surfaces for X-37

The final task currently in this element, Graphite/PETI-5 Composite Aero Surfaces for Test and Demo for X-37, will develop, test, and demonstrate in flight, Graphite/PETI-5 composites technology for warm primary structure for reusable space transportation vehicles. The final products will be ground test articles, ground test data, and flight hardware for the X-37 body flap, speed brake, and wings. Although the Graphite/PETI-5 flight articles are not going to provide significant weight savings to X-37 due design schedule limitations, the resin system that has a higher temperature capability would result in reduced TPS and insulation requirements, thus saving weight on future vehicles.

D. Thermal Protection Systems

The long-term major goals from the integrated thermal protection systems element of the project are envisioned to be:

- Necessary ground development and characterization of ultra-high temperature ceramics (UHCT's) which will enable sharp body hypersonic vehicles.
- Development and demonstration of highly reusable TPS with extended life cycle capabilities, including "most" weather flight capability and fail-safe performance.
- Understanding, assessment, simulation, and prediction of TPS degradation and failures
- A system for generating, capturing, and communicating TPS design, performance, and cost information to vehicle system analysis.

Currently there are five funded tasks in the thermal protection element.

1. High Temperature Felt TPS

The first task, High Temperature Felt TPS, is developing low cost, high temperature felts with a multiple use temperature limit to 1500 deg. F. Felt TPS offers the lowest unit area weight, installation time, inspection/replacement time, and total fabrication of current shuttle replacement options.

2. Quick Process, Low Cost Erosion Resistant TPS

The second task, Quick Process, Low Cost Erosion Resistant TPS, is developing a family of advanced TPS that are low cost and erosion resistant to allow for an "most" weather flight environment. Specific FY00-01 milestones are currently being determined.

3. Advanced High Temperature Structural Seals

The third task, Advanced High Temperature Structural Seals, is developing advanced control surfaces seals and demonstrating them in the appropriate environment. Higher temperature seals permit more aggressive structural components saving weight, enhancing performance, and reducing payload-to-orbit costs.

4. Subsurface Microsensors for Assisted Recertification of Thermal Protection Systems- SmarTPS

The fourth task, Subsurface Microsensors for Assisted Recertification of Thermal Protection Systems, will provide the vehicle inspector with a system which will allow for the use of a handheld receiver to rapidly detect subsurface TPS defects without touching the vehicle. The systems which consists of wireless embedded microsensors which are integrated with a thermal insulation database on a handheld computer. The receiver will send information to the portable computer where the required maintenance/repair action will automatically be recommended and approved through wireless communication with the main global operations crew. All of the inspection, maintenance and repair data will also be automatically transmitted to a TPS historical database. This system will eliminate the labor intensive detailed inspection and significantly reduce the paperwork required to report TPS discrepancies and their location, decide on a repair procedure, secure authorization for repair, and schedule a repair and final inspection. Paperwork accounts for approximately two thirds of the hours currently required to make repairs on Shuttle TPS.

5. Ultra-High Temperature Ceramics and SHARP L-1 Ground Development

The fifth task, Ultra-High Temperature Ceramics and SHARP L-1 Ground Development, will provide the necessary ground development and characterization of ultra-high temperature ceramics (UHTCs) and support the development and design of a flight test vehicle. The flight test vehicle will ultimately demonstrate a variety of sharp body technologies, including sharp UTHC leading edge, robust “most’ weather acreage TPS, and advanced control approaches for sharp bodies.

E. Aero/Aerothermodynamics Enhancement

The long-term major goals from the aero/aerothermodynamics enhancement element are envisioned to include the following:

- Design methods of complementary experimental and computational tools for rapid assessment of optimization of aerodynamic and aeroheating characteristics for proposed vehicle concepts in initial design.
- Reduce margins/uncertainties associated with complex flow phenomena. Emphasis will be on understanding transition and the effects of airframe design on aerodynamic and aerothermodynamic performance, airframe/propulsion integration, and control and interaction of external flow on airbreathing propulsion cycles.
- Aerodynamic optimization resulting from advanced flow physics techniques and devices.

No tasks are being funded in FY00 under this element.

VII. SCHEDULES

Level 1 milestones and changes to those milestones are shown in section XXIII. ***Milestones denoted by an asterisk and bold italic type are Level I milestones reported in Advanced Space***

Transportation and Vehicle Systems Technology Program Plans. Specific milestones for each task are listed by task below:

1.0 Integrated Airframe Design

1.1 Polymer Matrix Composite Damage Tolerance

FY00-01 milestones for this task are listed below:

- 1QFY00 - Access existing repair methods for structures made of skin-stiffeners and sandwich construction
- 3QFY00 - Develop analysis methods for sizing repairs
- 4QFY00 - Perform test to assess the pressure leakage thresholds for 3 material form concepts
- 4QFY00 - Perform combined loads tests on panels with delaminations and other known nondetectable defects
- 2QFY01 - Demonstrate repair methods for panels with skin-stiffeners construction
- 3QFY01 - Demonstrate repair methods for panels with sandwich construction
- 4QFY01 - Evaluate damage progression analysis methods to assess damage tolerance of composite structures

1.2 Safe Structures Analysis and Design Technologies

. FY00-01 milestones for this task are listed below:

- 4QFY00 - Develop nonlinear progressive failure analysis for composite structures subjected to combined loads and evaluate residual strength.

B. 4QFY01 - Develop composite structures damage tolerance criteria that relates structural weight and reliability

2.0 Integrated Thermal Structures and Materials

2.1 Integrated MPS Cryotank System

Due to significant funding reductions, the FY00-01 milestones for the task are currently being replanned.

2.2 Advanced Adhesives and Sealants

The FY00-01 milestones for the task are as follows:

- 2QFY00 - Select hot-melt adhesive candidate
- 4QFY00 - Select cryogenic sealant candidate
- 1QFY01 - Optimize performance of best adhesive

2.3 Non-autoclave Fabrication of Polymer Matrix Composites (PMCs)

The FY00-01 milestones for the task are as follows:

- 3QFY00 - Optimized e-beam cured polyimide
- 4QFY00 - Delivery of an acceptable e-beam or thermal non-autoclave curable resin/prepreg

- 4QFY00 - Development of a resin-fiber interface formulation that is stable to e-beam curing
- 4QFY00 - Demonstrate 550 deg. F capability for e-beam cured polyimide PMC
- 4QFY00 - Demonstrate viability of in-situ e-beam curing process
- 2QFY01 - Design and fabricate subcomponent with e-beam cured high-temperature polymer matrix composite

2.4 Carbon-Carbon Control Surface Modifications

The FY00-01 milestones for the task are as follows:

- 3QFY00 - Complete room and elevated temperature testing
- ***4QFY00 - Complete testing of modified carbon-carbon control surface***

  Output: Documentation of room and elevated temperature testing of modified torque tube control surface.

  Outcome: Refractory composite hot-structures control surfaces have the potential to eliminate the TPS requirement for advanced reusable launch vehicles which could potentially reduce weight, and reduce operation and maintenance requirements.
- 4QFY00 - Complete final report

2.5 Ultrasonic Spectroscopy for Composite Adhesive Bond Strength Determination

The FY00-01 milestones for the task are as follows:

- 3QFY00 - Ultrasonic evaluations
- 4QFY00 - Mechanical property evaluations
- 1QFY01 - Ultrasonic/mechanical correlation

2.6 Stitched, High Temperature Polymer Composite Cryotank Technology

The FY00-01 milestones for the task are as follows:

- 2QFY00 - Design concept selection
- 1QFY01 - New/modified resin evaluation
- 4QFY01 - Subcomponent fabrication and evaluation

2.7 Advanced Composite LOX Tank for X-34

. The FY00-01 milestones for the task are as follows:

- ***2QFY00 - Complete preliminary design of LOX tank for X-34***

  Output: Hold preliminary design review of composite LOX tank for X-34.

  Outcome: The tank being fabricated in this activity will become the first composite liquid oxygen tank to be flight tested. The long-term impact of utilizing low cost lightweight composites in liquid oxygen tank applications will be to reduce the cost of access to space

2.8 Graphite/PETI-5 Composite Aero Surfaces for X-37

The FY00-01 milestones for the task are as follows:

- 2QFY00 - Design complete
- 3QFY00 - Ground test complete
- 4QFY00 - Flight test hardware complete

3.0 Thermal Protection Systems

3.1 High Temperature Felt TPS

The FY00-01 milestones for the task are as follows:

- 3QFY00 - First material characterization arc jet test report
- ***4QFY00 - Characterization of various felt TPS concepts**

  Output: Measurement of thermal and mechanical properties, thermo-chemical stability assessment and durability screening in a vibro-acoustic environment of a variety of felt TPS concepts.

  Outcome: High temperature felts contribute to lower initial and recurring costs for reusable launch vehicles while enhancing their rapid turn-around capability.
- 1FY01 - Preliminary design evaluation arc jet test report

3.2 Quick Process, Low Cost Erosion Resistant TPS

Specific FY00-01 milestones are currently being determined.

3.3 Advanced High Temperature Structural Seals

The FY00-01 milestones for the task are as follows:

- 4QFY00 - Complete fabrication/feasbility-screening of leading seal candidates
- 4QFY01 - Demonstrate technology under simulated re-entry environment (arc-jet testing)

3.4 Subsurface Microsensors for Assisted Recertification of Thermal Protection Systems

The FY00-01 milestones for the task are as follows:

- 4QFY00 - Downselect thermal overlimit sensors for flight testing on Shuttle and X-34 in FY01
- 4QFY00 - Complete design of IVHM system for determination of waterproofing burnout depth
- 4QFY00 - Prototype TPS defect database
- 4QFY01 - Determine level of acceptable damage from MMOD and other impact during reentry for tile TPS
- 4QFY01 - Downselect impact sensors for flight testing on Shuttle and X-34 in FY02.

3.5 Ultra-High Temperature Ceramics and SHARP l-1 Ground Development

The FY00-01 milestones for the task are as follows:

- 4QFY00 - Complete multi-use UHTC leading edge design
- ***1QFY01 - Complete preliminary design of SHARP L-1**

  Output: Hold preliminary design review of SHARP L-1.

Outcome: SHARP L-1 will demonstrate a variety of sharp body technologies which will allow an entirely new generation of aero-space vehicle designs that have substantially improved affordability and capabilities for space access.

4.0 Aero/Aerothermodynamic Enhancement

No FY00-01 milestones are planned at this time.

VIII. RESOURCES

Funding for the Airframe Technology Project covers all effort, materials and services. The program funding plan by fiscal year are shown below:

A. Funding Requirements (NOA in Millions)

FY00	FY01	FY02	FY03	FY04	FY05	Totals
12.7	12.4	20.7	20.6	19.3	20.5	106.2

C. Institutional Requirements (FTE*)

FY00	FY01	FY02	FY03	FY04	FY05	Totals
TBD	TBD	TBD	TBD	TBD	TBD	TBD

IX. CONTROLS

The Airframe Technology Project is subject to the controls as contained in NASA Procedures and Guidelines, NPG 7120.5A. The Airframe Technology Project Plan establishes the top level technical, schedule, and cost controls placed on the program. An annual review of this plan will be performed to accommodate the changing nature of advanced technology projects. Responsibilities for Program and Project Management are as follows:

A. Headquarters Responsibilities

Associate Administrator for Aero-Space Technology

a. Providing program advocacy.
b. Establishing program requirements and metrics.
c. Recommending the level of GPMC oversight for each new program.

d. Assigning program and selected project responsibilities to Lead Centers.
e. Recommending new programs to the Agency PMC.
f. Developing, coordinating, and maintaining the PCA.
g. Approving Program Plans.
h. Assessing program performance against requirements and customer expectations.
i. Ensuring timely resolution of multiple program and project issues with assigned enterprise.
j. Serving as a member of the GPMC.
k. Allocating budgets to programs.

B. Center Responsibilities

1. The Lead Center Director (for ASTP it is MSFC and for AVSTP it is LaRC)

a. Serving as Chairperson of Lead Center PMC.
b. Supporting the Associate Administrator of the Aerospace Technology in program formulation.
c. Providing overall direction, control, and oversight of program implementation.
d. Appointing the program manager.
e. Concurring on the Program Plan for Associate Administrator approval.
f. Assigning work to other Centers.
g. Integrating institutional resources with program needs.
h. Coordinating cross-Center activities.
i. Ensuring compliance to policy/standards.
j. Maintaining dual path for Quality and IA.
k. Developing and maintaining program/project implementation policies and procedures compliant with NPD 7120.4, NPG 7120.5A, and ISO 9000.

2. Performing Center Director (LaRC)

a. Performing advanced concept studies in support of Agency and enterprise strategic plans.
b. Supporting the program formulation.
c. Project implementation and oversight.
d. Developing and maintaining program/project implementation policies and procedures compliant with NPD 7120.4, NPG 7120.5A, and ISO 9000.

3. ASTP and Vehicle Systems Technologies Program Managers

a. Program planning, including: recommendation of program objectives, requirements, implementation guidelines, program integration, budget and milestones, and preparation of Program Plans and PCA's.
b. Developing, recommending, and advocating the program resources.
c. Execution of the Program Plan and oversight.
d. Approving Project Plans and associated changes to these documents.
e. Reviewing and reporting program/project performance.
f. Establishment of project requirements and performance metrics.
g. Allocating budget to projects.
h. Control of program changes.
i. Establishing support agreements.

4. The Airframe Technology Project Manager

a. Preparation and maintenance of the Project Plan, specifications, schedules, and budgets.
b. Acquisition and utilization of participating contractors.
c. Execution of the Project Plan.
d. Reporting project status.
e. Approving Task Agreements.
f. Conducting design and all other appropriate reviews.
g. Participation in Configuration Control Board Activity.

X. IMPLEMENTATION APPROACH

A. Implementation Plan

The Airframe Technology Project will push the state-of-the-art in airframe and vehicle systems for low-cost, reliable, safe space transportation. The individual technologies within the project are focused on advanced, breakthrough technologies in airframe and vehicle systems and cross-cutting activities that are the basis for improvements in these disciplines. The key issues that will be addressed by the project are integrated airframe design, integrated thermal structures and materials, thermal protection systems, and aero/aerothermodynamics enhancements.

B. Project Summary WBS

1.0 Integrated Airframe Design
    1.1 Polymer Matrix Composite Damage Tolerance
    1.2 Safe Structures Analysis and Design Technologies
2.0 Integrated Thermal Structures and Materials

2.1 Integrated MPS Cryotank System
2.2 Advanced Adhesives and Sealants
2.3 Non-autoclave Fabrication of Polymer Matrix Composites (PMCs)
2.4 Carbon-Carbon Control Surface Modifications
2.5 Ultrasonic Spectroscopy for Composite Adhesive Bond Strength Determination
2.6 Stitched, High Temperature Polymer Composite Cryotank Technology
2.7 Advanced Composite LOX Tank for X-34
2.8 Graphite/PETI-5 Composite Aero Surfaces for X-37

3.0 Thermal Protection Systems
3.1 High Temperature Felt TPS
3.2 Quick Process, Low Cost Erosion Resistant TPS
3.3 Advanced High Temperature Structural Seals
3.4 Subsurface Microsensors for Assisted Recertification of Thermal Protection Systems
3.5 Ultra-High Temperature Ceramics and SHARP l-1 Ground Development

4.0 Aero/Aerothermodynamic Enhancement

XI. ACQUISITION SUMMARY

A number of competitive procurement actions involving various types of awards (cost-plus contracts, grants, etc.) will be used to successfully accomplish the project's goals. These include existing task assignment contracts with the major airframe companies. Because of the experimental nature of the Airframe Technology Project and tight time schedules, every emphasis will be placed on short procurement approaches. Existing contracts, NASA Research Announcements, Purchase Orders, and Support Agreements will be utilized to the greatest extent possible.

XII. PROGRAM/PROJECT DEPENDENCIES

Airframe Technologies has existing relationships to current and future aeronautics and space transportation programs. The Graphite/PETI-5 Composite Aero Surfaces for Test and Demonstration on X-37 task is required to comply with all requirements of the X-37 program. The Advanced Composite LOX Tank for X-34 task is required to comply with all requirements of the X-34 program.

XIII. AGREEMENTS

A. Internal NASA Agreements

Langley Research Center has been assigned as the Lead Center for the Airframe Technology Project and is responsible for project implementation and management. The Airframe Technology Project will require significant coordination between all participating centers. Coordination on specific technology development activities will be dictated by circumstances on an "as-needed" basis.

B. External Agreements

The Airframe Technology Project is expected to have external agreements through contractors and other agencies. All external agreements will be determined by competition as part of the overall acquisition strategy.

C. NASA/DoD Agreements

NASA has been assigned the Lead Agency for the development of Reusable Space Transportation systems, most of which have applicability for future DoD technology requirements. NASA and the Air Force have signed a Memorandum of Agreement calling for cooperative technology development and demonstration in support of NASA’s Advanced Space Transportation Program and the military Space Operations Vehicle.

XIV. PERFORMANCE ASSURANCE

Quality

Airframe Technology flight hardware designed, developed and built in-house at MSFC will be in accordance with the MPG 144.1. In-house hardware may be built to dated drawings with the approval of the Lead Systems Engineer, as specified in the Airframe Technology Configuration Control Plan. As built drawings will be submitted to the MSFC Configuration Control Process as specified in the Airframe Technology Configuration Control Plan. Airframe Technology flight hardware designed, developed, and built in-house at other Centers will be in accordance with the relevant Center policies and procedures.

Due to the limited scope of the Airframe Technology flight demonstration experiments, flight hardware may be commercial off-the-shelf as long as it meets the requirements specified in the governing specification documents.

Airframe Technology flight hardware purchased from outside vendors is not required to be ISO 9000 compliant. Airframe Technology flight hardware purchased from outside vendors will be based on the specific requirements of NHB 5300.4(1C). Tailoring of these requirements will be reflected in the Airframe Technology Quality Plan and/or in the vendor purchase order/contract.

Airframe Technology flight hardware purchased from outside vendors must be delivered with a Certificate of Compliance (COC) and an acceptance data package as specified in the purchase order or contract.

XV. RISK MANAGEMENT

Due to the advanced technology development program, an aggressive Risk Management Plan will be required to effectively manage the flight hardware in the Airframe Technology project. This plan will document a continuous process that:

- identifies risks
- analyzes their impact and prioritizes them
- develops and carries out plans for risk mitigation, acceptance, or other action
- tracks risks and the implementation of mitigation plans
- supports informed, timely, and effective decisions to control risks and mitigation plans
- assures that risk information is communicated among all levels of the project

Risk management begins in the formulation phase with an initial risk identification and development of a Risk Management Plan and continues throughout the product's life cycle through the disposition and tracking of existing and new risks. A risk management plan will be required only for the flight hardware elements of the project.

XVI. ENVIRONMENTAL IMPACT

Environmental impact assessment(s) shall be developed as needed by the appropriate center(s) Environmental Engineering and Management Office(s).

XVII. SAFETY

The Airframe Technology Project will utilize existing Center safety guidelines to provide for the early identification, analysis, reduction, and/or elimination of hazards that might cause the following:

- Loss of life or injury/illness to personnel
- Damage to or loss of equipment or property (including software)
- Unexpected or collateral damage as a result of tests

- Failure of mission
- Loss of system availability
- Damage to the environment

As required for specific tasks in the Airframe Technology Project a safety plan that details such activities as system safety, reliability engineering, electronic and mechanical parts reliability, quality assurance for both hardware and software, surveillance of the development processes, “closed loop” problem failure reporting and resolution, environmental design and test requirements will be developed. Mission success criteria shall be defined to aid in early assessment of the impact of risk management trade-off decisions. The safety and mission success activity shall accomplish the following:

- Provide for formal assessment and documentation of each hazard, with risks identified, analyzed, planned, tracked, and controlled.
- Provide for a safety assessment and certification regarding readiness for flight or operations, explicitly noting any exceptions arising from safety issues and concerns.
- Utilize a quality management system governed by the ISO 9000 standard, appropriate surveillance, and NASA Engineering and Quality Audit (NEQA) techniques.

XVIII. TECHNOLOGY ASSESSMENT

Ongoing assessment of needs for technology will be conducted by project management to insure that long term goals can be met.

XIX. COMMERCIALIZATION

Many of the technologies to be demonstrated have direct commercial application.

XX. REVIEWS

A. Management Reviews

Management Reviews will be scheduled during the life of the project. The type and frequency of the reviews will be established according to the unique needs of the Project and the Program Office. The reviews will be scheduled to keep program and project management informed of the current status of existing or potential problem areas. Agency management will be informed, in advance, of the schedule and agenda of the major reviews and will be invited to participate at their discretion. Special reviews by any level of management will be conducted when the need arises.

1. Lead Center Program Management Council (PMC) Review

As a project in both the Advanced Space Transportation Program and the Vehicle Systems Technology Program, the Airframe Technology Project will be reviewed during the lead Center Program Management Council Review of both of these programs. The reviews will cover overall status information, including schedule, change, performance, funding, interface coordination, and other management and technical topics. The Lead Center PMC review will also assess project progress against metrics and criteria proposed in procurement instruments.

2. Quarterly Program Review

A quarterly program review will be held to review cost, schedule, and technical issues. The location of the review will be determined on a case-by-case basis. Participants will include, as a minimum, the program managers of the ASTP and STD offices.

3. Other Reviews

Other independent reviews will be scheduled as required.

B. Technical Reviews

Each technology development effort will be reviewed at six-month increments to assess progress. Decisions for continuation, redirection, and/or cancellation will be made at that time.

XXI. TAILORING

The requirements of NASA Policy Directive (NPD) 7120.4A and NASA Procedures and Guidelines (NPG) 7120.5A apply to this program as tailored by the ASTP and Vehicle Systems Technology Program Plans.

XXII. RECORDS RETENTION

The Airframe Technology Project Manager will determine which project records will be retained and for how long in order to ensure a permanent record of the project and lessons learned are available to benefit future NASA projects. Governing documents will be kept in accordance with the required policies and procedures of the relevant Center.

XXIII. CHANGE LOG

EFF. DATE	STATUS	DOC. REVISION	DESCRIPTION
Dec 13, 1999	Baseline	-	Initial issue

Changes to Level 1 Deliverables